Topics in the November 2007 Exam Paper for CHEM1101

Click on the links for resources on each topic.

2007-N-2:

- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Shape of Atomic Orbitals and Quantum Numbers
- Material Properties (Polymers, Liquid Crystals, Metals, Ceramics)

2007-N-3:

- Nuclear and Radiation Chemistry

2007-N-4:

- Wave Theory of Electrons and Resulting Atomic Energy Levels
- Shape of Atomic Orbitals and Quantum Numbers

2007-N-5:

- Bonding - MO theory (larger molecules)

2007-N-6:

- Lewis Structures
- VSEPR

2007-N-7:

- Wave Theory of Electrons and Resulting Atomic Energy Levels

2007-N-8:

- Thermochemistry
- First and Second Law of Thermodynamics

2007-N-9:

- First and Second Law of Thermodynamics
- Electrolytic Cells

2007-N-10:

- Chemical Equilibrium

2007-N-11:

- Equilibrium and Thermochemistry in Industrial Processes

2007-N-12:

22/07(a) The University of Sydney

CHEMISTRY 1A - CHEM1101

SECOND SEMESTER EXAMINATION

CONFIDENTIAL

NOVEMBER 2007 **TIME ALLOWED: THREE HOURS**

GIVE THE FOLLOWING INFORMATION IN BLOCK LETTERS

FAMILY NAME		**SID NUMBER**	
OTHER NAMES		**TABLE NUMBER**	

INSTRUCTIONS TO CANDIDATES

- All questions are to be attempted. There are 20 pages of examinable material.
- Complete the written section of the examination paper in INK.
- Read each question carefully. Report the appropriate answer and show all relevant working in the space provided.
- The total score for this paper is 100. The possible score per page is shown in the adjacent tables.
- Each new short answer question begins with a •.
- Electronic calculators, including programmable calculators, may be used. Students are warned, however, that credit may not be given, even for a correct answer, where there is insufficient evidence of the working required to obtain the solution.
- Numerical values required for any question, standard electrode reduction potentials, a Periodic Table and some useful formulas may be found on the separate data sheets.
- Pages 12, 19 and 24 are for rough working only.

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Multiple choice section

	Marks	
Pages	Max	Gained
2-10	34	

Short answer section

Page	Marks Max	Gained		Marker
11	6			
13	6			
14	7			
15	5			
16	7			
17	6			
18	9			
20	5			
21	5			
22	5			
23	5			
Total	66			

	Marks
• In the spaces provided, explain the meanings of the following terms. You may use an equation or diagram where appropriate.	4
(a) Hund's rule	
(b) node	
(c) lyotropic liquid crystal	
(d) electron affinity	
• Sketch the following wave functions as lobe representations. Clearly mark all nodal surfaces and nuclear positions.	2

a π molecular orbital	a 2*s* atomic orbital

Marks

- Balance the following nuclear reactions by identifying the missing nuclear particle or nuclide. **3**

$$^{60}_{29}\text{Cu} \rightarrow \boxed{} + {}^{0}_{+1}\text{e}$$

$$\boxed{} + {}^{0}_{-1}\text{e} \rightarrow {}^{55}_{25}\text{Mn}$$

$$^{28}_{14}\text{Si} + {}^{2}_{1}\text{H} \rightarrow {}^{29}_{15}\text{P} + \boxed{}$$

- Calculate the following properties of the ^{13}N nuclide, given that its half-life is 9.96 minutes. **3**

(a) the decay constant in s^{-1}

Answer:

(b) the molar activity in Ci mol^{-1}

Answer:

Marks

- Calculate the energy (in J) and the wavelength (in nm) expected for an emission associated with an electronic transition from $n = 4$ to $n = 2$ in the Be^{3+} ion. **3**

Energy:	Wavelength:

- What two properties do electrons in atoms have which lead to discrete energy levels? Explain your answer. **2**

- What is the % transmission of a sample measured in an atomic absorption spectrometer to have an absorbance of 0.5? **2**

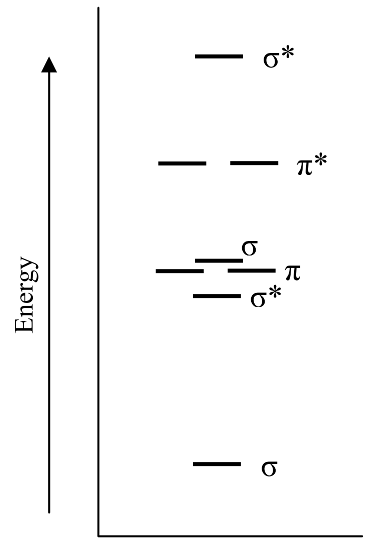
Answer:

Marks
5

- The following relate to the electronic structure of the N_2^- molecular ion.

How many valence electrons are in N_2^-?

The molecular orbital energy level diagram provided shows the energies of the orbitals for the valence electrons in N_2^-. Indicate on this diagram the ground state electronic configuration of N_2^- using the arrow notation for electron spins.



Calculate the bond order of N_2^-.

Is the bond strength in N_2^- stronger or weaker than the bond strength in N_2? Why?

Do you expect N_2^- to be paramagnetic? Explain your answer.

Marks
7

- Complete the table below showing the number of valence electrons, the Lewis structure and the predicted shape of each of the following species.

Formula	Total number of valence electrons	Lewis structure	Geometry of species
H_2O	8		V-shaped or bent
PCl_3			
COS			
ICl_3			

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
6

- Ozone in the upper atmosphere absorbs light with wavelengths of 220 to 290 nm. What are the frequency (in Hz) and energy (in J) of the most energetic of these photons?

Frequency:	Energy:

Carbon-carbon bonds form the backbone of nearly every organic and biological molecule. The average bond energy of the C–C bond is 347 kJ mol^{-1}. Calculate the wavelength (in nm) of the least energetic photon that can break this bond.

Wavelength:

Compare this value to that absorbed by ozone and comment on the ability of the ozone layer to prevent C–C bond disruption.

Marks
9

- Normal table sugar is pure sucrose, $C_{12}H_{22}O_{11}(s)$. Give the equation for the complete combustion of sucrose.

A standard can (375 mL) of soft drink contains 795 kJ of energy. Assume the only ingredients are water and sucrose and that the energy obtained from sucrose by the body is the same as that obtained by combustion. Tagatose, $C_6H_{12}O_6$, is a low-calorie sweetener with a calorific value to humans of only 6.2 kJ g^{-1}. On a weight for weight basis, it is 92% as sweet as sucrose. What mass of tagatose would be needed to produce a 375 mL can of drink with the same sweetness as a standard soft drink?

Data:

$\Delta_f H°$ ($C_{12}H_{22}O_{11}(s)$) = –2221.7 kJ mol^{-1}

$\Delta_f H°$ ($CO_2(g)$) = –393.5 kJ mol^{-1}

$\Delta_f H°$ ($H_2O(l)$) = –285.8 kJ mol^{-1}

Answer:

How much energy will a person obtain from this reduced-calorie can of soft drink?

Answer:

Marks

- Indicate the relative entropy of each system in the following pairs of systems. Use: “>”, “<”, or “=”. **2**

$CO_2(g)$		$CO_2(s)$
$O_2(g) + H_2O(l)$		$O_2(aq)$
hexane, $C_6H_{14}(g)$		pentane, $C_5H_{12}(g)$
$3O_2(g)$		$2O_3(aq)$

- An electrolytic cell contains a solution of MCl_3. A total charge of 3600 C is passed through the cell, depositing 0.65 g of the metal, M, at the cathode. What is the identity of the metal, M? **3**

Answer:

Marks
5

- Water (1.00 mol) was placed in an otherwise empty container with a fixed volume of 100 L. The container was heated to 1705 K, at which temperature the following equilibrium was established.

$$2H_2O(g) \rightleftharpoons 2H_2(g) + O_2(g) \qquad K_p = 1.89 \times 10^{-9} \text{ atm}$$

Calculate K_c for this reaction at 1705 K.

K_c =

Determine the amount of O_2 (in mol) in the container at equilibrium at 1705 K.

Answer:

Marks
5

- Ammonia is produced industrially by the direct combination of nitrogen and hydrogen. Write a balanced equation for the production of ammonia.

$\Delta_f H°$ for ammonia is –46 kJ mol^{-1}. A typical ammonia plant operates at a pressure of 250 atm and a temperature of 400 °C. Briefly explain the operation of an ammonia plant and the rationale for these conditions. What other "tricks of the trade" are used to maximise the production of ammonia?

THE REMAINDER OF THIS PAGE IS FOR ROUGH WORKING ONLY

Marks
5

- A voltaic cell consists of Zn^{2+}/Zn and Cu^{2+}/Cu half cells with initial concentrations of $[Zn^{2+}]$ = 1.00 M and $[Cu^{2+}]$ = 0.50 M. Each half cell contains 1.00 L of solution. What is the concentration of Cu^{2+} ions at 20 °C after equilibrium has been reached?

$[Cu^{2+}]_{eq}$ =

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DATA SHEET

Physical constants

Avogadro constant, $N_A = 6.022 \times 10^{23}$ mol^{-1}

Faraday constant, $F = 96485$ C mol^{-1}

Planck constant, $h = 6.626 \times 10^{-34}$ J s

Speed of light in vacuum, $c = 2.998 \times 10^{8}$ m s^{-1}

Rydberg constant, $E_R = 2.18 \times 10^{-18}$ J

Boltzmann constant, $k_B = 1.381 \times 10^{-23}$ J K^{-1}

Gas constant, $R = 8.314$ J K^{-1} mol^{-1}

= 0.08206 L atm K^{-1} mol^{-1}

Charge of electron, $e = 1.602 \times 10^{-19}$ C

Mass of electron, $m_e = 9.1094 \times 10^{-31}$ kg

Mass of proton, $m_p = 1.6726 \times 10^{-27}$ kg

Mass of neutron, $m_n = 1.6749 \times 10^{-27}$ kg

Properties of matter

Volume of 1 mole of ideal gas at 1 atm and 25 °C = 24.5 L

Volume of 1 mole of ideal gas at 1 atm and 0 °C = 22.4 L

Density of water at 298 K = 0.997 g cm^{-3}

Conversion factors

1 atm = 760 mmHg = 101.3 kPa

0 °C = 273 K

1 L = 10^{-3} m^{3}

1 Å = 10^{-10} m

1 eV = 1.602×10^{-19} J

1 Ci = 3.70×10^{10} Bq

1 Hz = 1 s^{-1}

Decimal fractions

Fraction	Prefix	Symbol
10^{-3}	milli	m
10^{-6}	micro	μ
10^{-9}	nano	n
10^{-12}	pico	p

Decimal multiples

Multiple	Prefix	Symbol
10^{3}	kilo	k
10^{6}	mega	M
10^{9}	giga	G

CHEM1101 - CHEMISTRY 1A

Standard Reduction Potentials, *E*°

Reaction	*E*° / V
$S_2O_8^{2-} + 2e^- \rightarrow 2SO_4^{2-}$	+2.01
$Co^{3+}(aq) + e^- \rightarrow Co^{2+}(aq)$	+1.82
$Ce^{4+}(aq) + e^- \rightarrow Ce^{3+}(aq)$	+1.72
$Au^{3+}(aq) + 3e^- \rightarrow Au(s)$	+1.50
$Cl_2 + 2e^- \rightarrow 2Cl^-(aq)$	+1.36
$O_2 + 4H^+(aq) + 4e^- \rightarrow 2H_2O$	+1.23
$Br_2 + 2e^- \rightarrow 2Br^-(aq)$	+1.10
$MnO_2(s) + 4H^+(aq) + e^- \rightarrow Mn^{3+} + 2H_2O$	+0.96
$Pd^{2+}(aq) + 2e^- \rightarrow Pd(s)$	+0.92
$Ag^+(aq) + e^- \rightarrow Ag(s)$	+0.80
$Fe^{3+}(aq) + e^- \rightarrow Fe^{2+}(aq)$	+0.77
$Cu^+(aq) + e^- \rightarrow Cu(s)$	+0.53
$Cu^{2+}(aq) + 2e^- \rightarrow Cu(s)$	+0.34
$Sn^{4+}(aq) + 2e^- \rightarrow Sn^{2+}(aq)$	+0.15
$2H^+(aq) + 2e^- \rightarrow H_2(g)$	0 (by definition)
$Fe^{3+}(aq) + 3e^- \rightarrow Fe(s)$	–0.04
$Pb^{2+}(aq) + 2e^- \rightarrow Pb(s)$	–0.13
$Sn^{2+}(aq) + 2e^- \rightarrow Sn(s)$	–0.14
$Ni^{2+}(aq) + 2e^- \rightarrow Ni(s)$	–0.24
$Co^{2+}(aq) + 2e^- \rightarrow Co(s)$	–0.28
$Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$	–0.44
$Cr^{3+}(aq) + 3e^- \rightarrow Cr(s)$	–0.74
$Zn^{2+}(aq) + 2e^- \rightarrow Zn(s)$	–0.76
$2H_2O + 2e^- \rightarrow H_2(g) + 2OH^-(aq)$	–0.83
$Cr^{2+}(aq) + 2e^- \rightarrow Cr(s)$	–0.89
$Al^{3+}(aq) + 3e^- \rightarrow Al(s)$	–1.68
$Mg^{2+}(aq) + 2e^- \rightarrow Mg(s)$	–2.36
$Na^+(aq) + e^- \rightarrow Na(s)$	–2.71
$Ca^{2+}(aq) + 2e^- \rightarrow Ca(s)$	–2.87
$Li^+(aq) + e^- \rightarrow Li(s)$	–3.04

CHEM1101 - CHEMISTRY 1A

Useful formulas

Quantum Chemistry	**Electrochemistry**
$E = h\nu = hc/\lambda$ $\lambda = h/mv$ $4.5k_BT = hc/\lambda$ $E = -Z^2E_R(1/n^2)$ $\Delta x \cdot \Delta(mv) \geq h/4\pi$ $q = 4\pi r^2 \times 5.67 \times 10^{-8} \times T^4$	$\Delta G° = -nFE°$ $Moles\ of\ e^- = It/F$ $E = E° - (RT/nF) \times 2.303 \log Q$ $= E° - (RT/nF) \times \ln Q$ $E° = (RT/nF) \times 2.303 \log K$ $= (RT/nF) \times \ln K$ $E = E° - \frac{0.0592}{n} \log Q$ (at 25 °C)
Acids and Bases	**Gas Laws**
$pK_w = pH + pOH = 14.00$ $pK_w = pK_a + pK_b = 14.00$ $pH = pK_a + \log\{[A^-] / [HA]\}$	$PV = nRT$ $(P + n^2a/V^2)(V - nb) = nRT$
Colligative properties	**Kinetics**
$\pi = cRT$ $P_{solution} = X_{solvent} \times P°_{solvent}$ $p = kc$ $\Delta T_f = K_f m$ $\Delta T_b = K_b m$	$t_{½} = \ln 2/k$ $k = Ae^{-E_a/RT}$ $\ln[A] = \ln[A]_o - kt$ $\ln \frac{k_2}{k_1} = \frac{E_a}{R}\left(\frac{1}{T_1} - \frac{1}{T_2}\right)$
Radioactivity	**Thermodynamics & Equilibrium**
$t_{½} = \ln 2/\lambda$ $A = \lambda N$ $\ln(N_0/N_t) = \lambda t$ ^{14}C age $= 8033 \ln(A_0/A_t)$	$\Delta G° = \Delta H° - T\Delta S°$ $\Delta G = \Delta G° + RT \ln Q$ $\Delta G° = -RT \ln K$ $K_p = K_c (RT)^{\Delta n}$
Miscellaneous	**Mathematics**
$A = -\log_{10} \frac{I}{I_0}$ $A = \varepsilon cl$ $E = -A \frac{e^2}{4\pi\varepsilon_0 r} N_A$	If $ax^2 + bx + c = 0$, then $x = \frac{-b \pm \sqrt{b^2 - 4ac}}{2a}$ $\ln x = 2.303 \log x$

PERIODIC TABLE OF THE ELEMENTS

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1 HYDROGEN **H** 1.008																	2 HELIUM **He** 4.003
3 LITHIUM **Li** 6.941	4 BERYLLIUM **Be** 9.012											5 BORON **B** 10.81	6 CARBON **C** 12.01	7 NITROGEN **N** 14.01	8 OXYGEN **O** 16.00	9 FLUORINE **F** 19.00	10 NEON **Ne** 20.18
11 SODIUM **Na** 22.99	12 MAGNESIUM **Mg** 24.31											13 ALUMINIUM **Al** 26.98	14 SILICON **Si** 28.09	15 PHOSPHORUS **P** 30.97	16 SULFUR **S** 32.07	17 CHLORINE **Cl** 35.45	18 ARGON **Ar** 39.95
19 POTASSIUM **K** 39.10	20 CALCIUM **Ca** 40.08	21 SCANDIUM **Sc** 44.96	22 TITANIUM **Ti** 47.88	23 VANADIUM **V** 50.94	24 CHROMIUM **Cr** 52.00	25 MANGANESE **Mn** 54.94	26 IRON **Fe** 55.85	27 COBALT **Co** 58.93	28 NICKEL **Ni** 58.69	29 COPPER **Cu** 63.55	30 ZINC **Zn** 65.39	31 GALLIUM **Ga** 69.72	32 GERMANIUM **Ge** 72.59	33 ARSENIC **As** 74.92	34 SELENIUM **Se** 78.96	35 BROMINE **Br** 79.90	36 KRYPTON **Kr** 83.80
37 RUBIDIUM **Rb** 85.47	38 STRONTIUM **Sr** 87.62	39 YTTRIUM **Y** 88.91	40 ZIRCONIUM **Zr** 91.22	41 NIOBIUM **Nb** 92.91	42 MOLYBDENUM **Mo** 95.94	43 TECHNETIUM **Tc** [98.91]	44 RUTHENIUM **Ru** 101.07	45 RHODIUM **Rh** 102.91	46 PALLADIUM **Pd** 106.4	47 SILVER **Ag** 107.87	48 CADMIUM **Cd** 112.40	49 INDIUM **In** 114.82	50 TIN **Sn** 118.69	51 ANTIMONY **Sb** 121.75	52 TELLURIUM **Te** 127.60	53 IODINE **I** 126.90	54 XENON **Xe** 131.30
55 CAESIUM **Cs** 132.91	56 BARIUM **Ba** 137.34	57-71	72 HAFNIUM **Hf** 178.49	73 TANTALUM **Ta** 180.95	74 TUNGSTEN **W** 183.85	75 RHENIUM **Re** 186.2	76 OSMIUM **Os** 190.2	77 IRIDIUM **Ir** 192.22	78 PLATINUM **Pt** 195.09	79 GOLD **Au** 196.97	80 MERCURY **Hg** 200.59	81 THALLIUM **Tl** 204.37	82 LEAD **Pb** 207.2	83 BISMUTH **Bi** 208.98	84 POLONIUM **Po** [210.0]	85 ASTATINE **At** [210.0]	86 RADON **Rn** [222.0]
87 FRANCIUM **Fr** [223.0]	88 RADIUM **Ra** [226.0]	89-103	104 RUTHERFORDIUM **Rf** [261]	105 DUBNIUM **Db** [262]	106 SEABORGIUM **Sg** [266]	107 BOHRIUM **Bh** [262]	108 HASSIUM **Hs** [265]	109 MEITNERIUM **Mt** [266]	110 DARMSTADTIUM **Ds** [271]	111 ROENTGENIUM **Rg** [272]							

LANTHANIDES	57 LANTHANUM **La** 138.91	58 CERIUM **Ce** 140.12	59 PRASEODYMIUM **Pr** 140.91	60 NEODYMIUM **Nd** 144.24	61 PROMETHIUM **Pm** [144.9]	62 SAMARIUM **Sm** 150.4	63 EUROPIUM **Eu** 151.96	64 GADOLINIUM **Gd** 157.25	65 TERBIUM **Tb** 158.93	66 DYSPROSIUM **Dy** 162.50	67 HOLMIUM **Ho** 164.93	68 ERBIUM **Er** 167.26	69 THULIUM **Tm** 168.93	70 YTTERBIUM **Yb** 173.04	71 LUTETIUM **Lu** 174.97
ACTINIDES	89 ACTINIUM **Ac** [227.0]	90 THORIUM **Th** 232.04	91 PROTACTINIUM **Pa** [231.0]	92 URANIUM **U** 238.03	93 NEPTUNIUM **Np** [237.0]	94 PLUTONIUM **Pu** [239.1]	95 AMERICIUM **Am** [243.1]	96 CURIUM **Cm** [247.1]	97 BERKELLIUM **Bk** [247.1]	98 CALIFORNIUM **Cf** [252.1]	99 EINSTEINIUM **Es** [252.1]	100 FERMIUM **Fm** [257.1]	101 MENDELEVIUM **Md** [256.1]	102 NOBELIUM **No** [259.1]	103 LAWRENCIUM **Lr** [260.1]